

**IMAGE SENSOR HAVING ABUTTING LINEAR ARRAYS**

The invention relates to the manufacture of large-dimension image sensors operating by relative translation between the image and the sensor. They are therefore linear sensors, that is to say sensors comprising one or more lines of photosensitive detectors and intended, during the relative translation between the image and the sensor, to reconstruct an overall image in two dimensions, namely one dimension in the direction of the line of photosensitive detectors and one dimension in the translation direction perpendicular to this line.

It will be understood that this definition includes linear array sensors with a plurality of lines, and in particular linear sensors of the TDI (Time Delay Integration) type which may comprise a plurality of lines, or even several tens of lines, intended to improve the signal/noise ratio of the detection by successive observation of a same image line by a plurality of detector lines.

For particular applications, for example observation of the earth from satellites, it is desirable to produce linear sensors of great length, more than that which can be produced on a single silicon chip, and for this purpose a plurality of chips may be aligned end-to-end in the direction of their length.

Figure 1 represents a top view of a row, on a printed circuit board 10, of a plurality of packages B1, B2, B3 ... each carrying a respective semiconductor chip P1, P2, P3 ... in the form of an array, each chip being electrically connected to its package by wires welded between connection terminals of the chip and connection terminals of the package.

The drawback of this layout is the presence of blind zones: even if the photosensitive points practically reach the edge of the chip and even if the chip practically reaches the edge of the package, the  
5 junction zones at the boundary between two chips will not contain photosensitive points (or pixels in image detection). In fact, the pixels will scarcely reach closer than about fifty micrometers from the edge of the chip, and the chip can only reach the edge of the  
10 package with a tolerance of the same order. For pixels having a pitch of about 10 micrometers, about ten pixels risk being absent in each abutment zone of adjacent packages. This is not acceptable because the overall image reconstructed in the course of the  
15 relative displacement of the sensor will comprise black columns in the translation direction.

Figure 2 represents a lateral section of a solution which has already been attempted in order to resolve  
20 this drawback: the photographic optics project the image to be detected not directly onto the photosensitive sensor but onto the plane entry face of a set of optical fiber bundles F1, F2, F3 ...; the fiber bundles F1, F2, F3 are juxtaposed and leave no  
25 gap between them on the side of their entry face; each bundle is deformed by tightening the side turned toward the chip, however, so that its exit face occupies only the useful length of the linear array. The blind zones are thus eliminated. This solution is very expensive,  
30 in particular because of the extreme precision which is required in the juxtaposition of the fiber bundles and in the deformation of these bundles so that their exit occupies exactly the active photosensitive length of each array.

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Figure 3 represents a more practical solution which may be envisaged: the chips abut, although in a staggered fashion; they are therefore not aligned, or more

exactly they are divided into two groups of aligned chips and the two groups form two parallel rows, each chip of the second group being placed between two separated chips of the first group but offset out of  
5 the row of chips of the first group. The distance between two chips of a row is less than the length of the package of a chip. The packages therefore bear against one another at the end, along an edge parallel to the row direction; the ends of the adjacent chips  
10 comprise detection zone portions in mutual overlap so that there is absolutely no dead zone. The separation of the row axes of the two groups is equal to the width  $L$  of the package. It is perfectly known and, when photographing in translation, taking into account the  
15 translation speed  $V$ , an image line is reconstructed by combining the information provided by two adjacent chips not at the same time but with a time interval  $L/V$ , which compensates for the fact that the chips do not see the same image line at the same time.

20 This solution suffers from drawbacks associated with the need to reconstruct the final image, with risks of distortion and instability which are commensurately more problematic as the distance between the two chip  
25 rows is greater. The distance is moreover equal to the width of the package, that is to say several centimeters.

30 One possible solution for limiting this drawback is represented in Figure 4: the chips are all placed at the edge of the package, all the wires connecting the chip to the package being relocated to one side of the chip. The chips are still staggered, and the signal which they provide therefore has to be processed in  
35 order to carry out reconstruction, taking into account the offset of the row axis of the chips, although this offset is now practically only the width of the chip and no longer the width of the package.

Unfortunately, this solution is expensive because it requires a particular chip design, having connection terminals on only one side, and it may furthermore 5 require the use of two different components depending on whether the chip belongs to one row or the other because the chips are alternately reversed; reversal, however, is not necessarily compatible with the operation of the chip. This is the case in particular 10 for multilinear arrays operating in TDI (Time Delay Integration) mode, or multispectral imaging arrays having a plurality of lines of pixels corresponding to different colors or ranges of the spectrum. This is because reversal of the chip entails signal processing 15 problems in both cases. This solution is therefore difficult to implement.

In order to further improve the staggered abutment, with mutual overlap of the photosensitive zones in 20 order to avoid blind zones, the present invention principally relates to a sensor whose package, instead of being simply rectangular as is conventionally the case, comprises two small lateral extensions substantially with the same width as the chip and with 25 a length substantially equal to the mutual overlap desired between the chips. These extensions extend in the length direction of the chip. The chip practically entirely covers these extensions (which do not contain connection terminals). The extensions of two packages 30 are adjacent (in physical contact or almost in physical contact) via their side parallel to the row of chips. There is no connection terminal on the substrate in the region of the lateral extensions.

35 There is therefore a staggered abutment, with an inter-axial distance equal to the width of the chips or nearly so, without having the need to design a special component (this is because the terminals can lie on

both sides of the chip) and without having the need for two different components, one for each of the rows, as is the case in the arrangement of Figure 4.

5 The invention therefore relates to an image sensor comprising a plurality of linear image detection arrays associated in order to form a linear image sensor with a length greater than that of each array, characterized in that the arrays are mounted on packages whose upper  
10 surface has an elongate rectangular shape provided on two opposite short sides of the rectangle with two extensions substantially covered by the ends of the array, the packages being mounted in a staggered fashion and two packages being adjacent via a  
15 respective extension of each of them. These extensions have a width smaller than that of the short sides of the rectangle. There are no connection terminals on the packages, so that they can all be identical and juxtaposed without reversal.

20 A variant may nevertheless be envisaged in which the chips protrude from a rectangular package without extensions of this rectangular package supporting them. This variant is less favorable because it subjects the  
25 chips to stresses which are not always compatible with severe environmental conditions, particularly from the point of view of shocks and vibrations; on the other hand, the grounding of the chip on its entire rear face is inferior, as is the thermal dissipation.

30 In order to take account of these two possibilities according to the invention, the following general definition of the invention has been formulated: a large-dimension image sensor operating by relative  
35 translation of the image with respect to the sensor, comprising a plurality of individual monolithic chips each capable of detecting a linear image portion perpendicular to the translation direction, the

individual chips being arranged in two groups, the chips of one group being aligned in order to detect aligned image portions and the chips of the other group being aligned in order to detect other image portions  
5 which are aligned but offset with respect to the chips of the first group in the relative translation direction, the chips of the second group being arranged in a staggered fashion with respect to the chips of the first group so that all the chips of the first group  
10 lie beside at least one chip of the second group, the chips each being mounted on a package, connection wires being connected between connection terminals of the package and connection terminals on the upper surface of the chip, characterized in that the upper surface of  
15 the package, on which the chip is mounted, comprises a principal zone the shape of which is an elongate rectangle whose length is less than the length of the chip and whose width is greater than that of the chip, all of the connection terminals lying inside this  
20 rectangle along the chip, all the chips having two ends protruding from the rectangle, a protruding end of a chip being adjacent, via a side parallel to the row of chips, to a side likewise parallel to the row of chips of the protruding edge of another chip. The packages  
25 are all identical and juxtaposed without reversal.

The chip end therefore protrudes according to the invention either into emptiness or on an extension of the package extending the rectangular zone in the  
30 general direction of the length of the rectangle.

In the embodiment with a rectangular package having two extensions lying under the chip protrusions, the dimension of these extensions, in length in the  
35 direction of the row and in width in the translation direction of the image, is preferably only just greater than the length and width of the protruding chip part which covers this extension. Only a positioning

tolerance margin is provided, for example of the order of 50 to 100 micrometers, is provided around the chip in order to take into account risks of poorly positioning the chip on the package.

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Other characteristics and advantages of the invention will become apparent on reading the following detailed description, which is given with reference to the appended drawings in which:

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- Figures 1 to 4, already described, represent various possibilities of mounting linear arrays in order to constitute a large-dimension sensor;

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- Figure 5 represents a first possibility of the abutment of arrays according to the invention, having a package provided with two extensions and a chip covering these extensions;

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- Figure 6 represents a package according to the invention in more detail;

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- Figure 7 represents an alternative embodiment with a rectangular package without extension and with a protruding chip.

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Figure 5 shows the linear sensor according to the invention, with a plurality of linear chips abutting in a staggered fashion with partial overlap between the ends of the chips. The staggered chips form two parallel rows, the axes of which are straight lines D1 and D2 parallel to the translation direction Ox of the image with respect to the sensor.

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The first row comprises the odd rank linear chips P1, P3, etc., each carried by a respective package B1, B3, and the line passing linearly through the centre of the chips is the straight line D1. The second row comprises

the even rank chips P2, P4 carried by the respective packages B2, B4 etc. and their central line is the straight line D2.

5 The straight lines D1 and D2 are separated by a distance L which is equal to or slightly greater (for example by 100 to 200 micrometers) than the width of the chips (the width counted along the direction Ox, for example equal to a few millimeters). This width is  
10 much less than that of the packages which support them (one or several centimeters), so that the spacing L of the straight lines D1 and D2 is much less than that which exists in Figure 3. The chips are all identical and mounted identically on their package, in contrast  
15 to the case of Figure 4.

The packages, all of which are identical, have an elongate overall shape since the chips are linear arrays (one line or several lines), and they therefore  
20 have two long sides parallel to the straight lines D1 and D2 and two short sides at the ends of these long sides. The short sides each comprise an extension or "lug" which extends the package in the direction of the straight lines D1 and D2. The chip mounted on a package  
25 essentially covers the upper surface of these extensions, although a slight margin (50 to 100 micrometers) may nevertheless be provided on all the edges of the extension so that the package protrudes beyond the surface of the chip in the region of the  
30 extension.

The staggered packages bear against one another via their extensions: the packages are in contact along edges parallel to the straight lines D1 and D2. On the  
35 other hand, the extension of a package may bear against a short side of the package wherever there is no extension.

The packages are therefore positioned very precisely with respect to one another so long as the dimensions (width and length) of the extensions are precisely machined.

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Since the width of the extensions (in the translation direction Ox) is only just greater than the width of the chip, the connections between the chip and the package are produced exclusively in the principal zone 10 of the upper surface of the package, and not in the extensions: there is no connection terminal on the upper surface of the package in the extensions.

In other words, the upper surface of the package has an 15 elongate rectangular shape with two long sides and two short sides, and an extension protruding from the rectangle on each short side, and the connection terminals all lie inside the rectangle which constitutes the principal zone of the package, the 20 extension constituting an auxiliary zone.

The staggered chips mutually overlap in the region of the extensions, that is to say the chip comprises useful photosensitive points in the region of the 25 extensions, and the photosensitive points of an odd rank chip see a given image line slightly before the photosensitive points of an adjacent even rank chip see the same image line. If the translation speed is  $V$  and if the distance between the straight lines  $D1$  and  $D2$  is 30  $L$ , then the even rank line will see the same image line after a time  $L/V$ . In order to obtain an image in two dimensions during the image reconstruction, care will be taken to associate the signals provided at a time  $t$  by the odd rank chips with the signals provided by the 35 even rank chips at time  $t+L/V$ .

The photosensitive points which are in mutual overlap make it possible to avoid having any blind zone in the

line of arrays of photosensitive points: most of the points of an image line are seen by a single array, but the points are seen twice in the overlap zone, once at time  $t$  and once at time  $t+L/V$ ; simple image processing 5 makes it possible to give a single value to these points, which value may be the one read by one chip or the other chip, or the average of the two values read, optionally weighted as a function of the position of the point on the array.

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The length of the extensions may correspond to the length necessary in order to place several tens of photosensitive points on the extension. With an array 15 several centimeters long and photosensitive points with a pitch of 10 micrometers, for example, 1 millimeter extensions may be provided. In an example of a spatial imaging sensor, the length of the package may be 5 centimeters, the width of the package may be from 1 to 2 cm, and the width of the chip may be 2 or 3 20 millimeters.

Figure 6 shows in more detail a top view of an even rank package B2 abutting with an odd rank package B3.

25 The overall shape of the principal part of the upper surface of the package is an elongate rectangle, with two long sides 20 and 22 and two short sides 24 and 26, and the short sides are provided with two extensions 30 and 32, respectively on the left and right of the 30 package, which extend parallel to the elongation direction of the rectangle.

The chip P2, in the form of a linear array, is 35 electrically connected to the package B2 by connection wires joining terminals 28 of the chip to terminals 34 of the package. It is exclusively on the rectangular principal surface of the package, delimited by the long sides 20 and 22 and the short sides 24 and 26, that the

electrical connection terminals 34 are located. There are no wire connection terminals on the extensions 30 and 32 which, as can be seen, are almost entirely covered by the chip. If absolutely necessary, it is 5 feasible for there to be terminals 28 on the chip in the region of the extension, these wires leading to terminals 34 of the package in the principal zone.

The packages B2 and B3 abut via their respective 10 extensions, the right extension 32 in the case of the package B2 and the left extension 30' in the case of the package B3: the left end of the extension 30' of the package B3 bears on the right short side 26 of the package B2 (or almost bears on it, if it is preferable 15 that there should not completely be mechanical contact at this position); likewise, the extension 32 of the package B2 bears (or almost bears) against the left short side of the package B3; furthermore, in order to define the spacing between the lines of even rank and 20 odd rank chips, the extensions 32 and 30' bear (or almost bear) against each other in the direction Ox via their lateral edges, which are perpendicular to the translation direction (edges parallel to the elongation direction of the arrays) and which face each other when 25 the packages are put in place staggered.

The spacing L between the elongation axes of the arrays of photosensitive points of the two rows of chips is equal to the width of the extension, the chip being 30 placed at the centre of the extension so that all the chip+package assemblies are identical. The width of the extension is equal to the width of the chip, to which may be added a positioning tolerance margin of a few tens of micrometers (preferably from about 50 35 micrometers to 200 micrometers, for example 50 or 100 micrometers) all around the chip. The margin at the end of the extension may be greater, so long as there are a sufficient number of photosensitive points in the

extension in order to ensure overlap of the images taken by two adjacent chips.

Figure 6 represents the zone Z in which the  
5 photosensitive points 40 and 40', belonging  
respectively to the chips P2 and P3, are in mutual  
overlap, that is to say they can see (albeit at  
different times) the same points of an image line  
translating in the direction Ox perpendicular to the  
10 lines of photosensitive points.

As mentioned above, each chip in the form of an  
elongate array may comprise one or several lines of  
photosensitive points 40. In particular, there are a  
15 plurality of lines in TDI type arrays.

Figure 7 represents an alternative embodiment which is  
less beneficial than that of figure 6 owing to the  
greater sensitivity of the layout to shocks and  
20 vibrations and owing to the inferior thermal and  
electrical performances of the sensors. There is no  
lateral extension on the package in this variant, and  
the package is exactly rectangular with two long sides  
20 and 22 and two short sides 24 and 26, although the  
25 chip protrudes laterally on the right and left of the  
package so that it is the chip itself which constitutes  
the extension used for abutment.

The staggered packages are abutted by making the chips  
30 touch via their protruding lateral edges. The end of  
one chip touches (or almost touches) a short side of  
the adjacent package, and a protruding lateral edge of  
the chip touches (or almost touches) a protruding  
lateral edge of the adjacent chip. The spacing between  
35 the axes of the line of even rank chips and the line of  
odd rank chips is in this case equal to the width of  
the chips. The image overlap is obtained via the

protruding parts of the adjacent chips, which see the same points of an image line.

The invention is more particularly applicable to  
5 multilinear arrays (several lines of pixels) operating  
in TDI (Time Delay Integration) mode, in which the  
signals observed by a line are added to the signals  
observed by the preceding line in synchronism with the  
translation of the array; it is also particularly  
10 applicable to multispectral arrays in which several  
lines of pixels are provided, each line corresponding  
to a given color or spectral band; the invention is  
more generally applicable to high-resolution imaging,  
in particular for spatial imaging.